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(54) A METHOD OF DETERMINING THE DENSITY PROFILE

VERFAHREN ZUR BESTIMMUNG DES DICHTEPROFILS

PROCEDE DE MESURE D'UN PROFIL DE DENSITE

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(56) References cited:
WO-A-95/35491
US-A- 4 123 654
US-A- 4 228 351
US-A- 4 380 817

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Description

Technical Field.

[0001] The invention relates to a method of determining the density profile of a plate-shaped material as described in the preamble of claim 1.

Background Art

[0002] Danish Patent Application No. 0723/94 discloses a method of determining the density profile of plate-shaped materials by way of a measuring of Compton-scattered radiation from small partial volumes in the material. During the measuring, a predetermined angular relation is maintained between the incident and the scattered radiation, and the scattered radiation is adjusted by a simultaneous measuring of the incident radiation intensity and the attenuation in the entire plate-shaped material. However, such a measuring method only makes allowance for singly scattered radiation.

[0003] It is known from the article "The characterisation of multiple scattering in Compton profile measurements" by T. Pitkanen in Nuclear Instruments and Methods i Physics Research A257 (1987) pp 384-390 that multiple scattered radiation is rather important in connection with relatively thick plates.

Brief Description of the Invention

[0004] The object of the invention is therefore to provide a method of determining the density profile of a plate-shaped material, said method being more accurate than hitherto known.

[0005] The method according to claim 1 is far more accurate than hitherto known, especially in connection with relatively thick plates.

Brief Description of the Drawing

[0006] The invention is explained in greater detail below with reference to the accompanying drawing, in which

Fig. 1 illustrates how the measured intensity of the scattered radiation is composed of several values,

Fig. 2 shows a measuring arrangement wherein an additional detector is coupled between the X-ray source and the plate-shaped material,

Fig. 3 shows an arrangement of two plate-shaped materials arranged at a mutual distance, and

Fig. 4 shows an example of how one of the parameter values β varies versus the height of the plate material.

Best Mode for Carrying Out the Invention

[0007] Fig. 1 shows how the measured intensity of the scattered radiation is composed of contributions from the considered partial volume at P and contributions from multiple scattered radiation either in the plate-shaped material M itself, where scattered radiation from the entire length AB can cause a renewed scattering from the length CD in a direction towards the detector F, or via a collimator where scattered radiation from the length AB meets the wall of said collimator and is scattered towards the detector F.

[0008] The intensity of the multiple scattered radiation is not correlated with the density of the partial volume at P, but almost unambiguously correlated with the surface weight ρt of the plate-shaped material M, where ρ is the average density and t is the thickness.

[0009] The latter has been confirmed by simulation calculations performed by the known Monte-Carlo-method. For the present measuring geometry with a narrow incident beam and a strong collimation in front of the detector for scattered radiation and an optical thickness of $\mu \cdot \rho \cdot t<1$, where μ is the absorption coefficient, the intensity of multiple scattered radiation I_{MS} can be approximately expressed by

$$(1) \qquad I_{MS} = \beta \cdot I_0 \cdot \mu \cdot \rho \cdot t \cdot (1-\alpha \cdot \mu \cdot p \cdot t)$$

where I_0 is the incident intensity.

[0010] I_{MS} is proportional to the intensity I_0 of incident radiation, and the parameters α and β depend on the actual measuring geometry (the extent of the beam, the visual field of and the distance to the collimator and the detector etc. Furthermore, β depends on the position of P of the actual partial volume, from which singly scattered radiation is to be measured. When the location P_1 is considered outside the plate M, a definite probability applies of multiple scattered radiation over the length AB through C', D' or E' to the staggered detector, I_{MS} decreases, however, proportional to an increasing distance to C', D' from AB.

[0011] The above observations result in a possibility of compensating for multiple scattered radiation in the following manner.

[0012] As shown in Fig. 2, a detector TK is placed between the X-ray source K and the plate-shaped material M. The detector TK measures the time-related variation of the intensity of the source K. Together, the measuring signal from the detector TK and the transmitted measuring signal T provide the relation

$$e^{-\mu\rho t} = \frac{TK}{T} \text{ or } \mu\cdot\rho\cdot t = \ln\frac{TK}{T}$$

where μ is the absorption coefficient, ρ is the density, and t is the thickness, whereafter the adjusted density ρ_{korr} is found for a partial volume at P according to Danish patent application No. 0723/94 by a deduction of $I_{MS}(P)$ as

$$(2) \qquad \rho_{korr}(P) = C \cdot \frac{I_{FS}(P) - I_{MS}(P)}{T} =$$

$$c \cdot \left(\frac{I_{FS}(P)}{T} - \frac{TK}{T} \cdot \beta(P) \cdot \ln\frac{TK}{T} \cdot \left(1 - \alpha \cdot \ln\frac{TK}{T} \right) \right)$$

where $T = I_0 e^{-\mu\rho t}$ or $TK = I_0 \cdot k$ (k = constant fraction of the intensity of the X-ray tube Measured as I_0 at T for an empty measuring gap) has been adjusted by the factor k and where I_{FS} is the intensity of the radiation measured by the detector F.

[0013] The parameters α, β are determined by way of a calibration measuring for the actual measuring arrangement. In Fig. 3 two plates M', M" are interspaced a distance corresponding to the length of approximately three partial volumes. When I_{FS} is measured from the resulting air gap between the plates M', M", only multiple scattered radiation is measured. The measuring of I_{FS} is repeated with another set of plates (larger/smaller thickness and/or higher/lower density), which results in two equations with two unknown quantities for determining a and β. The variation of β-with P relative to the central value is subsequently determined by means of a set of. plates of thicknesses corresponding to 3-4 partial volumes, between which an air gap is established at various depths.

[0014] As the effect of multiple scattered radiation is vague (approximately 10% (corresponding to the value of α) of singly scattered radiation measured in a typical measuring object of a density of approximately 1g/cm^3), it is sufficient to know the absolute contribution at the centre of the plate-shaped material. Subsequently the relative variation of β from the lower edge to the upper edge measured for one thickness can be utilized for calculating the multiple scattering contribution across plates of an arbitrary-thickness.

[0015] in practice, the density profile measuring device is supplemented with an optical thickness meter, such as an optical reflection meter, whereby both the size

$$\mu\cdot\rho\cdot t = \ln\frac{TK}{T}$$

as the thickness t are found in a computer at the beginning of the production and are continuously updated. Based on the thickness t the position of the detector F is calculated, said position corresponding to "O", "½ t" and "t". As far as the central position corresponding to ½ t is concerned, the values of a and β are taken from a table. A function $\beta(P)$ renders it possible to calculate the relative variation of β across the measured thickness, whereafter the measured scattering densities are adjusted by means of formula (2).

[0016] The selection of angle of incidence and scattering angle as well as the utilization of the signals from the three detectors follow the method according to Danish patent application No. 0723/94.

[0017] A γ-ray source may be used instead of an X-ray source.

Claims

1. A method of determining the density profile of a plate-shaped material (M), the density of which varies discretely or continuously across the plate thickness, whereas the density at a specific depth of said plate is preferably assumed to be constant, such as for instance wood-based plates, by means of X-rays or γ-rays from a source (K) being arranged on one side of said plate (M), whereby at least two detectors (T,F) are arranged on the opposite side of the endless plate being advanced in the longitudinal direction during the endless measuring, one first detector (T) being placed in the radiating direction of the source (K) so as to measure the radiation transmitted through the plate (M), and at least one detector (F) being placed outside the radiating direction of said source (K) so as to measure the radiation scattered from partial volumes along the radiating direction of the source (K), characterised by compensating for multiple scattered radiation in each individual partial volume by subtracting the multiple scattered radiation from the measured scattered radiation, said multiple scattered radiation being calculated by means of the formula

$$I_{MS} = \beta \cdot I_0 \cdot \mu \cdot \rho \cdot t \cdot (1 - \alpha \cdot \mu \cdot \rho \cdot t)$$

   where I_0 represents the incident intensity, μ is the absorption coefficient, ρ is the average density of the plate (M), t is the thickness, and α and β depend on the measuring arrangement.

2. A method as claimed in claim 1, characterised by a calibration by means of two sets of two plates each set with a gap between the two plates for determining α and β from two equations for the density in the gap whereby the equations are based on said formula.

3. A method as claimed in claim 1 or 2, characterised by determining the relative variation of β with respect to the position of the partial volumes by means of a set of plates of thicknesses corresponding to several partial volumes at various depths, an air gap being established between said plates at the various depths.

Patentansprüche

1. Verfahren zur Bestimmung des Dichteprofils eines plattenförmigen Materials (M), dessen Dichte diskret oder kontinuierlich über die Plattendicke variiert, während die Dichte in einer speziellen Tiefe der Platte als vorzugsweise konstant angenommen wird, wie z.B. Platten auf Holzbasis, mittels Röntgenstrahlen oder Gammastrahlen von einer Quelle (K), die auf einer Seite der Platte (M) angeordnet ist, wobei wenigstens zwei Detektoren (T,F) auf der gegenüberliegenden Seite der endlosen, in die Längsrichtung während des endlosen Messens fortbewegten Platte angeordnet sind, wobei ein erster Detektor (T) in der Strahlungsrichtung der Quelle (K) so platziert ist, dass er die durch die Platte (M) hindurchgehende Strahlung misst, und wenigstens ein Detektor (F) außerhalb der Strahlungsrichtung der Quelle (K) so platziert ist, dass er die von Partialvolumina entlang der Strahlungsrichtung der Quelle (K) gestreute Strahlung misst, dadurch gekennzeichnet, dass die mehrfach gestreute Strahlung in jedem einzelnen Partialvolumen kompensiert wird, indem die mehrfach gestreute Strahlung von der gemessenen gestreuten Strahlung subtrahiert wird, wobei die mehrfach gestreute Strahlung mittels der Formel

$$I_{MS} = \beta \cdot I_0 \cdot \mu \cdot p \cdot t \cdot (1 - \alpha \cdot \mu \cdot p \cdot t)$$

   berechnet wird, wobei I_0 die Einfallsintensität darstellt, μ der Absorptionskoeffizient ist, p die Durchschnittsdichte der Platte (M) ist, t die Dicke ist und α und β von der Messanordnung abhängen.

2. Verfahren nach Anspruch 1, gekennzeichnet durch ein Kalibrieren mittels zweier Sätze von zwei Platten, wobei jeder Satz mit einem Zwischenraum zwischen den zwei Platten zur Bestimmung von α und β aus zwei Gleichungen für die Dichte in dem Zwischenraum versehen ist und wobei die Gleichungen auf der besagten Formel basieren.

3. Verfahren nach Anspruch 1 oder 2, gekennzeichnet durch Bestimmung der relativen Variation von β in Bezug auf

die Position der Partialvolumina mittels eines Satzes von Platten mit Dicken, die mehreren Partialvolumina in verschiedenen Tiefen entsprechen, wobei ein Luftspalt zwischen den Platten in verschiedenen Tiefen angeordnet ist.

Revendications

1. Procédé de détermination du profil de densité d'un matériau en forme de plaque (M), dont la densité varie de façon discrète ou continue sur l'épaisseur de la plaque, alors que la densité à une profondeur spécifique de ladite plaque est de préférence supposée être constante, comme par exemple pour des plaques à base de bois, au moyen de rayons X ou de rayons γ provenant d'une source (K) qui est disposée d'un côté de ladite plaque (M), dans lequel au moins deux détecteurs (T, F) sont disposés du côté opposé de la plaque sans fin qui est agencée dans la direction longitudinale durant la mesure sans fin, un premier détecteur (T) étant placé dans la direction de rayonnement de la source (K) de façon à mesurer le rayonnement transmis au travers de la plaque (M), et au moins un détecteur (F) étant placé à l'extérieur de la direction de rayonnement de ladite source (K) de façon à mesurer le rayonnement diffusé à partir de volumes partiels le long de la direction de rayonnement de la source (K), caractérisé par la compensation d'un rayonnement diffusé multiple dans chaque volume partiel individuel en soustrayant le rayonnement diffusé multiple du rayonnement diffusé mesuré, ledit rayonnement diffusé multiple étant calculé au moyen de la formule

$$I_{MS} = \beta . I0 . \mu . \rho . t . (1 - \alpha . \mu . p . t)$$

où I_0 représente l'intensité incidente, μ représente le coefficient d'absorption, p représente la densité moyenne de la plaque (M), t est l'épaisseur, et α et β dépendent de l'agencement de mesure.

2. Procédé selon la revendication 1, caractérisé par un étalonnage au moyen de deux ensembles de deux plaques, chaque ensemble présentant un intervalle entre les deux plaques afin de déterminer α et β d'après deux équations pour la densité dans l'intervalle, d'où il résulte que les équations sont fondées sur ladite formule.

3. Procédé selon la revendication 1 ou 2, caractérisé par la détermination de la variation relative de β par rapport à la position des volumes partiels au moyen d'un ensemble de plaques d'épaisseurs correspondant à plusieurs volumes partiels à diverses profondeurs, un intervalle d'air étant établi entre lesdites plaques aux diverses profondeurs.

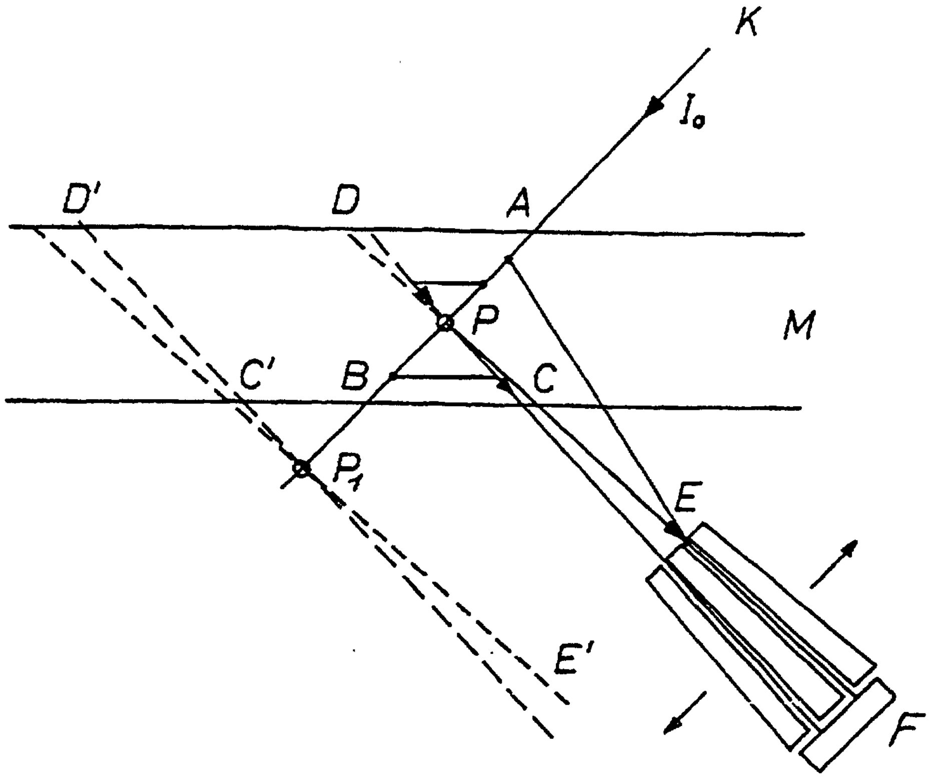

Fig. 1

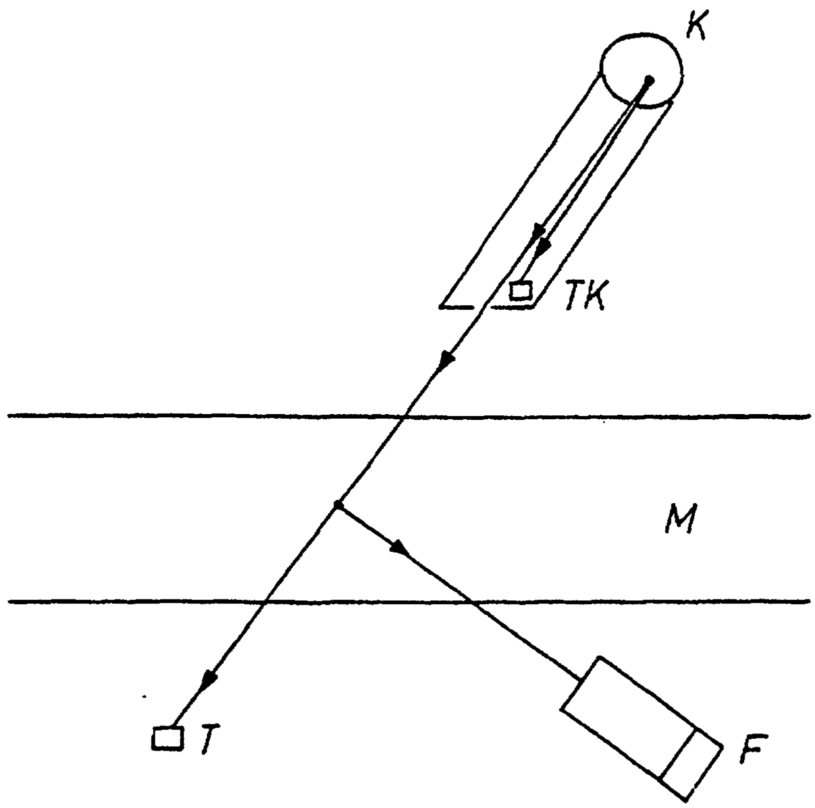

Fig. 2

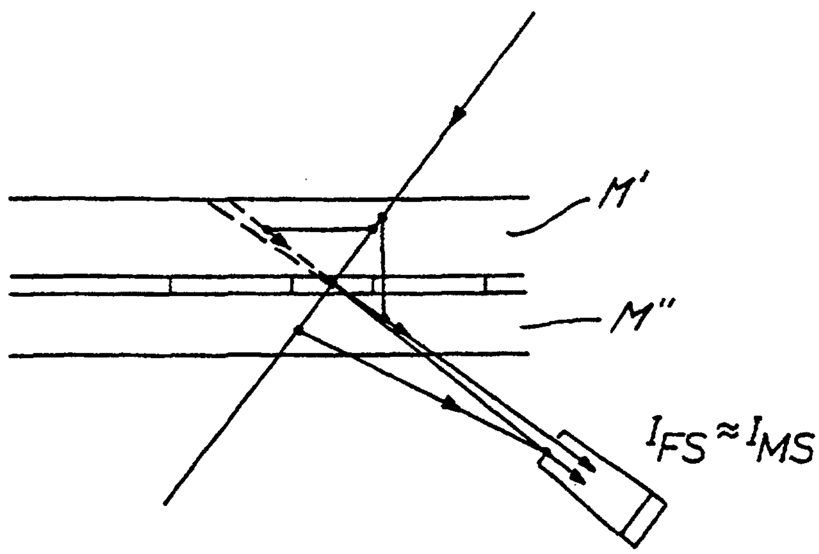

Fig. 3

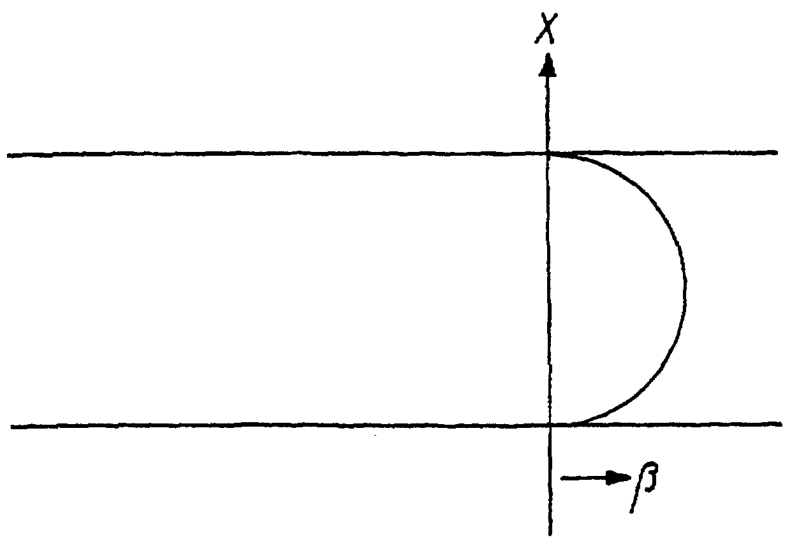

Fig. 4